REMARKS

Claims 1-48 are in the case and have been amended to avoid multiple dependent claims. Please calculate the fee based on no multiple dependent claims, and if any multiple dependent claims remain, it is requested that they be amended to depend from lowest numbered claim referred to.

Respectfully submitted,

Peter C. Michalos
Reg. No. 28,643
Attorney for Applicants
(212) 564-0200

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NOTARO & MICHALOS P.C.
350 Fifth Avenue - Suite 6902
New York, New York 10118-6985

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Method for producing coated substrates

Field and Background of the Invention

The present invention relates to a method for producing material-charged substrates in which

a) at least one substrate is introduced into an evacuated vacuum container;

b) the surface of the substrate to be charged is exposed to a reactive gas which is adsorbed on the surface;

c) the exposure of the surface to the reactive gas is terminated,

d) the reactive gas adsorbed on the surface is allowed to react.

Such a method is prior known from US 5 916 365. Therein a substrate is introduced into an evacuated vacuum container with a container wall comprised of ceramics, delimiting the process volume against the environment.

The surface to be coated of the substrate is exposed to a first reactive gas, which is adsorbed on said surface. The exposure of the surface to the reactive gas is terminated by subsequently pumping off the reactive gas.

A second reactive gas is subsequently introduced and, by means of a coil configuration provided outside of the vacuum container, an electromagnetic high-frequency field is generated in the container. Thereby at least a portion of the introduced second reactive gas is activated to form radicals, and the first reactive gas adsorbed on the surface, is allowed to react exclusively with said radicals generated by the effect of the high-frequency field.

The present invention addresses the problem of proposing a method of the above listed type, which builds on the deposition of a monolayer of atoms on the surface of the substrate to be coated, but has a substantially expanded flexibility of application with respect to the variety of monolayers which can be deposited.

Summary of the Invention

We are herein addressing charging with materials for the reason that said monolayer does not need to be deposited as a continuous layer in the sense of a coating, but rather the density of deposited atoms can be far lower than is necessary for the formation of a continuous layer. But, if desired, the material charging can readily take place such that a continuous monolayer is formed, in this case in the sense of a coating.

This is attained according to the invention thereby that

d_1) the surface with the adsorbed reactive gas is exposed to a low-energy plasma discharge with ion energy E_{I0} on the surface of the substrate of

$$0 < E_{I0} \leq 20 \text{ eV}$$

and an electron energy E_{eo} of

$$0 \text{ eV} < E_{eo} \leq 100 \text{ eV},$$

d_2) the adsorbed reactive gas is allowed to react at least with the cooperation of plasma-generated ions and electrons.

In contrast to said US 5 916 365 where the adsorbed gas is exclusively allowed to react with radicals, which by definition are electrically neutral, according to the invention the reactive gas adsorbed on the surface is also allowed to react mildly through the effect of ions and electrons generated by low-energy plasma discharge. Therewith the feasibility is given of properly stabilizing the adsorbed gas also without effect of radicals of a further reactive gas on the surface, solely through "mild" interaction with low-energy inert gas ions and electrons or through such effect by other reactive gas ions.

Although the cited US 5 916 365 explains that it was prior known to deposit thin coatings with the inclusion of a glow discharge in an atmosphere of a mixture of reactive gases, but which did not lead to satisfactory coating formation, in the course of the present description it will be explained how the plasma discharge employed

dynamically. In a further preferred embodiment the cathode-anode gap for the plasma discharge is disposed essentially perpendicularly and preferably centrally with respect to said surface.

In a further preferred embodiment of the method according to the invention, during the generation of the plasma discharge a magnetic field is generated in the process volume and the plasma density distribution along the surface is adjusted or controlled stationarily and/or dynamically by means of this field. The plasma density distribution is preferably at least locally wobbled, leading to an effect as if the substrate held stationarily in the plasma were moved with respect to the discharge.

Moreover, preferably at least the reactive gas or gas mixture to be adsorbed is introduced into the process volume such that it is distributed, preferably with an inflow direction substantially parallel to the substrate surface and, further preferred, with injection sites equidistant from the substrate surface. In an especially preferred embodiment of said method, the substrate is formed by a silicon oxide-coated substrate with channels sunk into the silicon layers, wherein after carrying out n-times the step d_2) copper is deposited into the channels. In every case n is therein greater than 1.

Brief Description of the Drawings

In the following the invention will be explained in conjunction with Figures. Therein depict:

Fig. 1 schematically a first embodiment variant of a process module for carrying out the method according to the invention, in particular its phases Ph_1 and/or Ph_2,

Fig. 2 in a representation analogous to that of Figure 1, a preferred embodiment variant of the process module according to Figure 1,

Fig. 3 in a representation analogous to Figure 1 or 2, a further type of process module for carrying out cleaning steps by the method according to the invention,

Fig. 4 in a representation analogous to Figures 1 to 3, a modification of the process module depicted in Figure 3,

Fig. 5 simplified a preferred embodiment of a process module according to Figure 2, convertible into a process module according to Figure 3 or 4,

Fig. 6 with respect to a nozzle axis A of the process module according to Figure 5, the spatial and time modulation caused by the control of components of the magnetic field parallel to axis A over a plane E, perpendicularly to nozzle axis A,

Fig. 7 by example and schematically a method according to the invention for multilayer realization,

Fig. 8 a further embodiment of a method according to the invention with multilayer realization, and

Fig. 9 in top view and simplified the combination of process modules according to Figures 1 to 5 to form a circular or cluster installation for carrying out the method according to the invention.

Description of the Preferred Embodiments

In Figure 1 is schematically depicted a process module of type I preferably employed for carrying out the method according to the invention. A chamber wall 1 of a vacuum container 3 encompasses a process volume PR. In the process volume PR is provided a substrate carrier 5. The process volume PR is pumped down via a pumping connection 11, such as is shown schematically with vacuum pump 13, to